MUST 382 / EELE 491

Spring 2014

Operational Amplifiers, Part 1

Operational Amplifiers ("Op Amps") are an extremely important component for a wide range of low power audio electronic circuits. The term *operational* refers to the use of op amps in electronic circuits which perform arithmetic *operations* on the input voltages (or currents) applied to the circuit. Although the concept of an operational amplifier dates back to the era of World War II, the development of *integrated circuits* (ICs) from the 1960's to the present has resulted in a large number of op amp types and features. Many general purpose op amps in IC form cost less than 50 cents. In fact, the *socket* the op amp IC plugs into may cost as much or more than the amp itself!!

The op amp is depicted schematically as shown in Figure 1. The figure shows the two op amp inputs: "-" for the inverting input and "+" for the non-inverting input; the op amp output, and the power supply connections. Note that an op amp does not have a "ground" pin. The op amp input is *differential*, so it gets its ground reference implicitly through the signal and power supply connections. *NOTE also that the power supply connections are not always shown explicitly in diagrams, but power connections must be included in the actual circuit.*

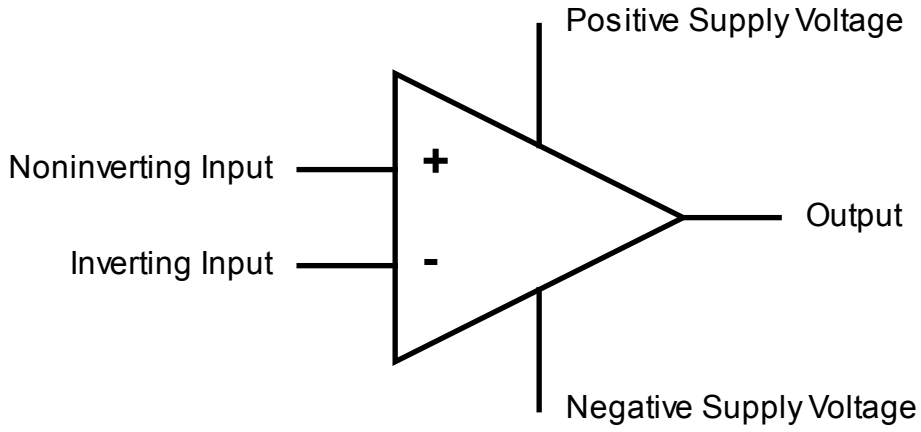


Figure 1

A simple integrated circuit op amp is shown in Figure 2. The circuit is contained in a *dual in-line package*, or DIP for short. The DIP has a notch, dot, or stripe at one end to indicate the correct orientation of the circuit. The standard part number is usually printed on the top of the DIP. Note that the pin numbers are assigned in counter clockwise order viewed from above, beginning at the notch end. In addition to the two inputs, the two power supply pins, and the output, notice that this particular op amp has three other pins: one labeled *NC*, meaning no connection, and two labeled *offset*

null. The offset null pins allow us to make small adjustments to the internal currents in the IC in order to force the output voltage to be zero (null) when the inputs are both zero in order to compensate for the anticipated manufacturing variations from chip to chip. We will not need to use the offset null feature for now, so no connections will be made to the offset null pins. It is also important to realize that there is no "ground" pin on the op amp: the amp receives its ground reference via the external components and connections of the complete circuit.

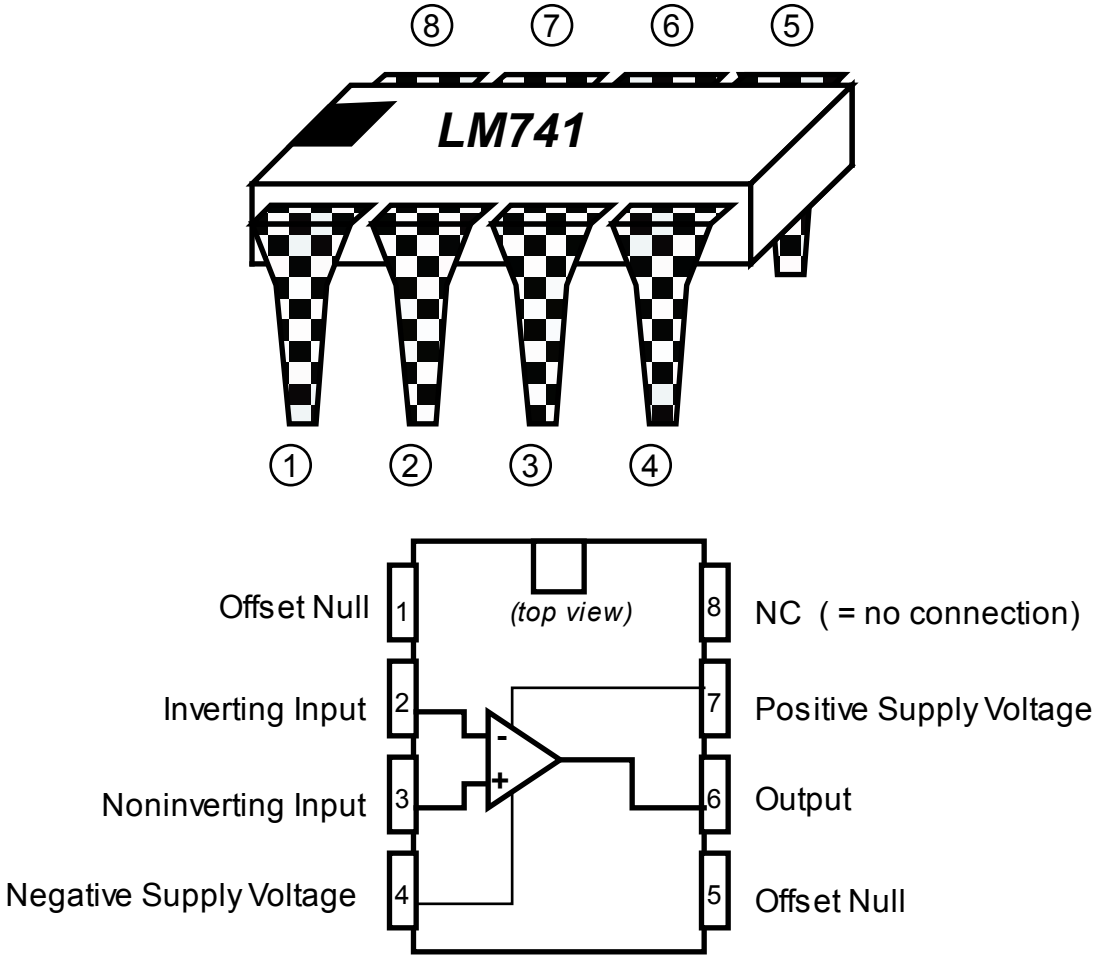


Figure 2

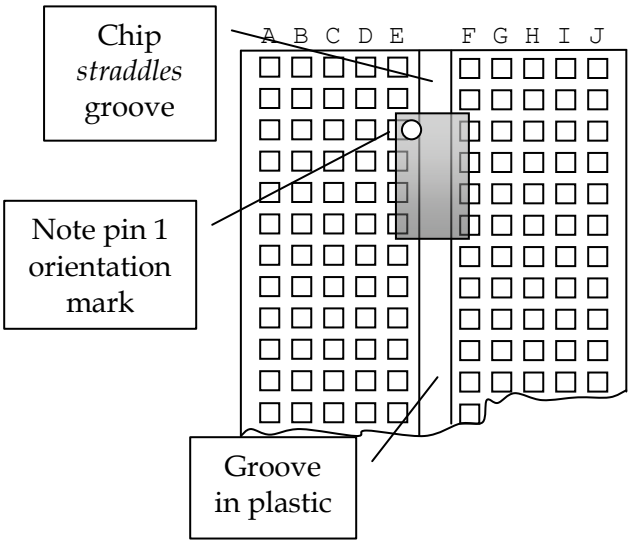
While the particular IC shown in Figure 2 contains a single op amp, many other IC types are produced which feature different pin connections, and some chips have two or more op amps in a single DIP package.

Integrated circuit op amps behave very much like the conceptually "ideal" op amp used in circuit analysis. There are some important limitations to keep in mind, however. First, the supply voltages cannot exceed some maximum rating, typically ±18 V DC. The op amp will usually operate using lower voltage supplies, *but exceeding the maximum rating will destroy the*

IC. Second, the output voltage from an IC op amp is usually limited to be a volt or two smaller than the power supply voltages, e.g., the output voltage swing of an op amp with ±15 V supplies is, perhaps, ±13 V. Third, the output current from most op amps is limited to 30 mA or so, meaning that the load resistance attached to the output must be large enough that no more than the maximum current flows when the output voltage is maximum.

IC op amps have many other characteristics that will be considered in subsequent experiments and readings. *When in doubt about the limitations of an op amp it is best to refer to the manufacturer's data sheet*.

In the lab, ALWAYS REMEMBER TO ASSEMBLE THE CIRCUIT WITH THE POWER OFF, then TEST and VERIFY the bench supply to make sure the voltages are correct BEFORE applying power to the circuit. Start with the function generator set for minimum output.



It is common to include *power supply bypass capacitors* in op amp circuit designs. Capacitors are charge storage elements. *Bypass* refers to the good design practice of placing capacitors across the power supply connections to help stabilize the DC power supply voltages and "bypass" any noise or interference on the supply lines to ground.

This means connecting small (typically 0.01μF or 0.1μF) capacitors between the positive supply voltage and the circuit ground and between the negative supply voltage and circuit ground, as shown in Figure 3. The bypass capacitors should be placed as close to the IC as possible.

Many different types of op amps are available from commercial manufacturers. The type 741 op amp used in this lab was originally introduced by Fairchild Semiconductor in 1968, so it is an "old," reliable, well-understood, and inexpensive IC. *The 741 is by no means the best op amp for every purpose*: more recent designs reflect the advances of

integrated circuit technology that have taken place over the last 50+ years. The 741 op amp is simply a good example of the so-called *general purpose* operational amplifiers that are used in everything from radios and wireless telephones to car engine control systems and the International Space Station.

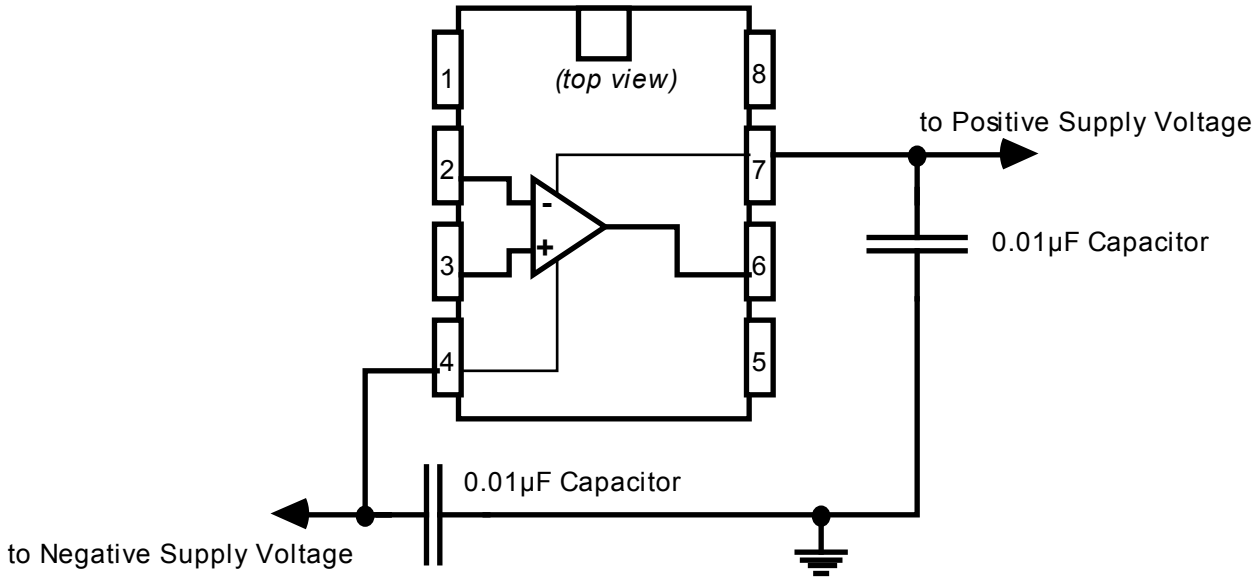


Figure 3